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Lab Exercises –

```
clc;
```

Constants for Heli 4

```
Mh = 1.450; % Mass of Heli Body (kg)
Mc = 1.918; % Mass of CW (kg)
La = 25.75/39.37; % Distance from Pivot to Helecopter body center (m)
Lb = 18.5/39.37; % Distance from Pivot to conterweight center (m)
Lh = 6.933; % Distance from pitch axis to rotor center (m)
Kf = 0.140; % Motor-Prop Force Constant (N/V)
Krt = 0.0027; % Motor-Prop Torque Constant (Nm/V)
epsilon = -26:1:30; % Elevation Range (Deg)
epsilon_0 = -25.75; % Elevation Start (Deg)
lambda = 0:1:360; % Travel Range (Deg)
g = 9.81; % Gravity constant (m/s^2)
Wh = Mh*g; % Weight of Heli Body (N)
Wc = Mc*g; % Weight of CW (N)

Je = (Mh * La^2) + (Mc * Lb^2) % Elevation Axis (kg-m^2)

% Open loop transfer function
G4_elev1 = tf(La*Kf, [Je, 0, 0])
G4_elev2 = tf(0.0294, [1.0000, 0.1538, 1.3288])
G4_elev3 = tf(0.0911, [1.0000, 3.1682, 1.7900, 4.0932])
G4_trav = tf(0.002362, [1 0 0])

% Closed loop transfer function
T = tf(La*Kf, [Je, 0, 0] + La*Kf)

% Load Sisotool data
% sisotool('SisoElev1.mat') % originaly sisotool('rlocus', G4_elev1)
% sisotool('SisoElev2.mat') % originaly sisotool('rlocus', G4_elev2)
% sisotool('SisoElev3.mat') % originaly sisotool('rlocus', G4_elev3)
% sisotool('Trav.mat') % originaly sisotool('rlocus', G4_trav)


Je =
```

```
    1.0438


G4_elev1 =

   0.09157
  ---------
  1.044 s^2

Continuous-time transfer function.

G4_elev2 =

          0.0294
  ----------------------
  s^2 + 0.1538 s + 1.329

Continuous-time transfer function.

G4_elev3 =

               0.0911
  --------------------------------
  s^3 + 3.168 s^2 + 1.79 s + 4.093

Continuous-time transfer function.

G4_trav =

  0.002362
  --------
    s^2

Continuous-time transfer function.

T =

              0.09157
  -----------------------------
  1.135 s^2 + 0.09157 s + 0.09157

Continuous-time transfer function.
```

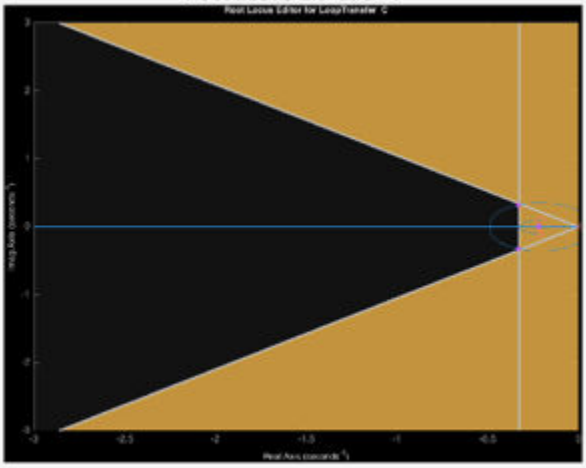
Question 1

Root Locus and Step Response for Elevation 1

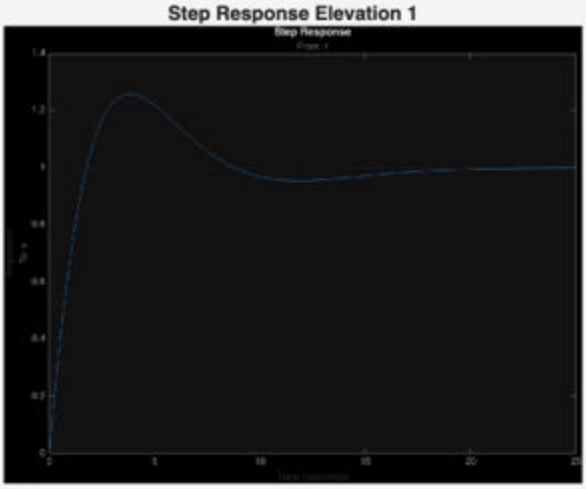
```
figure(1)
image(imread("Elev1RL.png"))
title('Root Locus Elevation 1')
axis off
```

```
figure(2)
image(imread("Elev1SR.png"))
title('Step Response Elevation 1')
axis off

% Root Locus and Step Response for Elevation 2
figure(3)
image(imread("Elev2RL.png"))
title('Root Locus Elevation 2')
axis off

figure(4)
image(imread("Elev2SR.png"))
title('Step Response Elevation 2')
axis off

% Root Locus and Step Response for Elevation 3
figure(5)
image(imread("Elev3RL.png"))
title('Root Locus Elevation 3')
axis off

figure(6)
image(imread("Elev3SR.png"))
title('Step Response Elevation 3')
axis off

figure(7)
image(imread("TravRL.png"))
title('Root Locus Travel')
axis off

figure(8)
image(imread("TravSR.png"))
title('Step Response Travel')
axis off
```

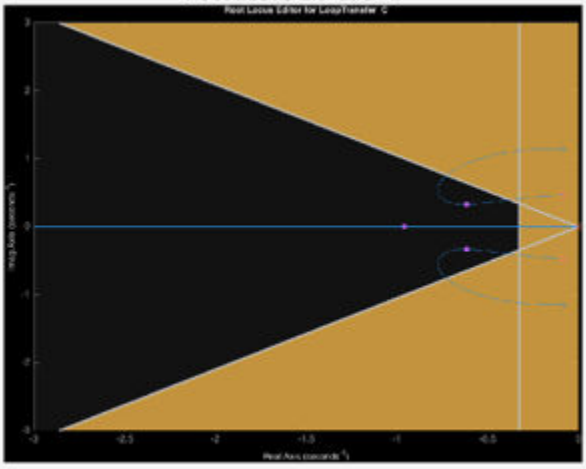
Root Locus Elevation 1



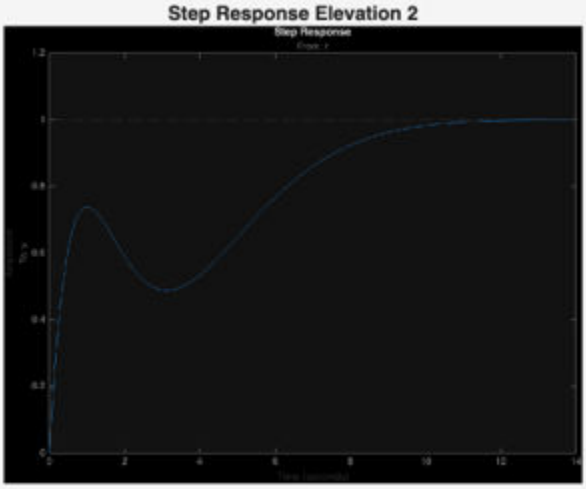
Step Response Elevation 1



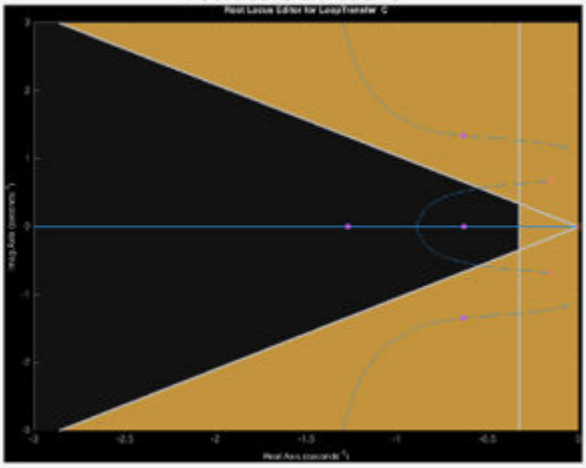
Root Locus Elevation 2



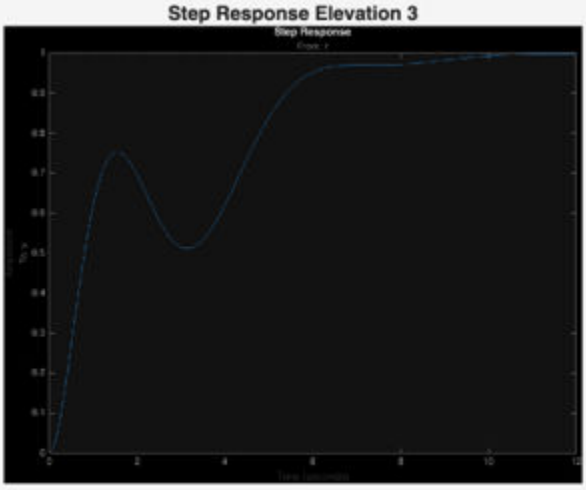
Step Response Elevation 2

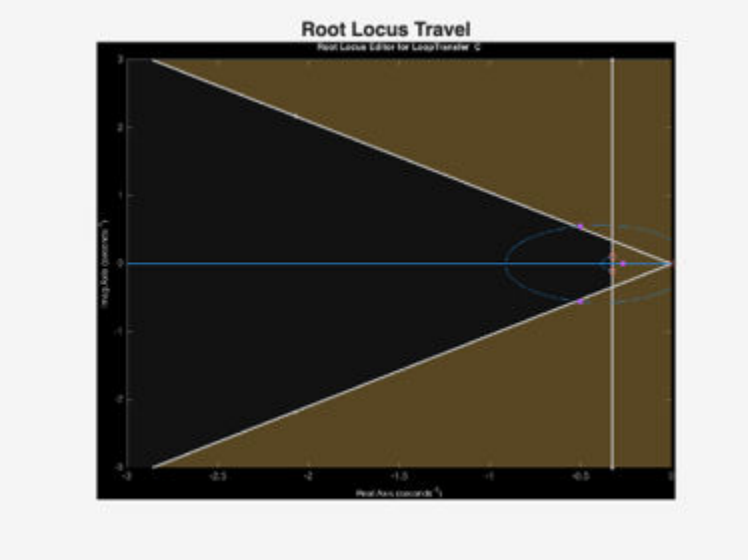


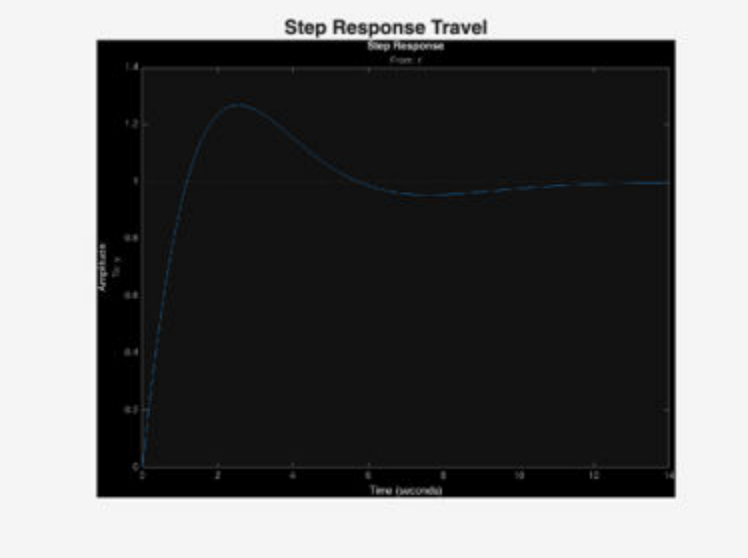
Root Locus Elevation 3



Step Response Elevation 3







Question 2

Tranfer functions

```
G4_elev1 = tf(La*Kf, [Je, 0, 0])
G4_elev2 = tf(0.0294, [1.0000, 0.1538, 1.3288])
G4_elev3 = tf(0.0911, [1.0000, 3.1682, 1.7900, 4.0932])
G4_trav = tf(0.002362, [1 0 0])

% PID gain values of each tranfer function
PID1 = pid(C1)
PID2 = pid(C2)
PID3 = pid(C3)
PID_Trav = pid(C_Trav)


G4_elev1 =
```

```
   0.09157
  ---------
  1.044 s^2

Continuous-time transfer function.

G4_elev2 =

          0.0294
  ----------------------
  s^2 + 0.1538 s + 1.329

Continuous-time transfer function.

G4_elev3 =

              0.0911
  --------------------------------
  s^3 + 3.168 s^2 + 1.79 s + 4.093

Continuous-time transfer function.

G4_trav =

  0.002362
  --------
    s^2

Continuous-time transfer function.

PID1 =

             1
  Kp + Ki * --- + Kd * s
             s

  with Kp = 4.12, Ki = 0.539, Kd = 10.1

Name: C
Continuous-time PID controller in parallel form.

PID2 =

             1
  Kp + Ki * --- + Kd * s
             s

  with Kp = 11.6, Ki = 15.9, Kd = 69.3

Name: C
Continuous-time PID controller in parallel form.

PID3 =
```

```
             1
  Kp + Ki * --- + Kd * s
             s

  with Kp = 12.1, Ki = 19.3, Kd = 39.8

Name: C
Continuous-time PID controller in parallel form.

PID_Trav =

             1
  Kp + Ki * --- + Kd * s
             s

  with Kp = 351, Ki = 63.4, Kd = 540

Name: C
Continuous-time PID controller in parallel form.
```

Question 3

Comlete closed loop transfer function

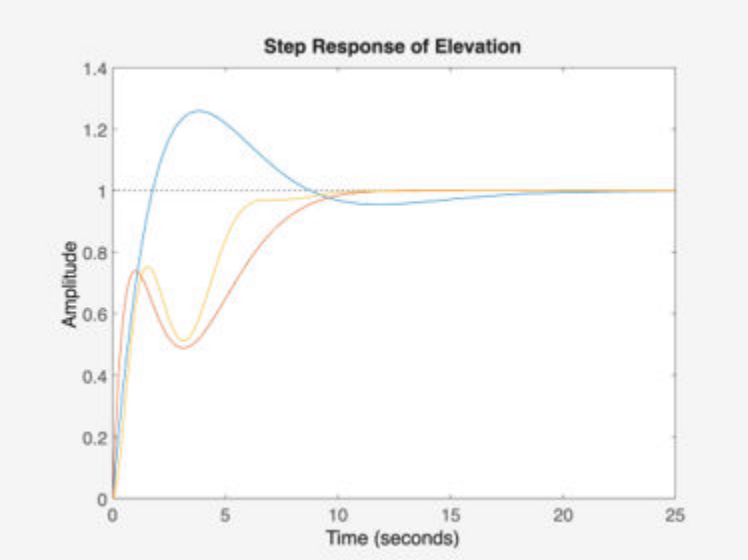
```
feedback_elev1 = feedback(G4_elev1*PID1, 1)
feedback_elev2 = feedback(G4_elev2*PID2, 1)
feedback_elev3 = feedback(G4_elev3*PID3, 1)
feedback_trav = feedback(G4_trav*PID_Trav, 1)


feedback_elev1 =

         0.9218 s^2 + 0.3769 s + 0.04935
  ----------------------------------------
  1.044 s^3 + 0.9218 s^2 + 0.3769 s + 0.04935

Continuous-time transfer function.

feedback_elev2 =

     2.036 s^2 + 0.34 s + 0.4683
  --------------------------------
  s^3 + 2.19 s^2 + 1.669 s + 0.4683

Continuous-time transfer function.

feedback_elev3 =

           3.623 s^2 + 1.106 s + 1.762
  ------------------------------------------
  s^4 + 3.168 s^3 + 5.413 s^2 + 5.199 s + 1.762

Continuous-time transfer function.
```

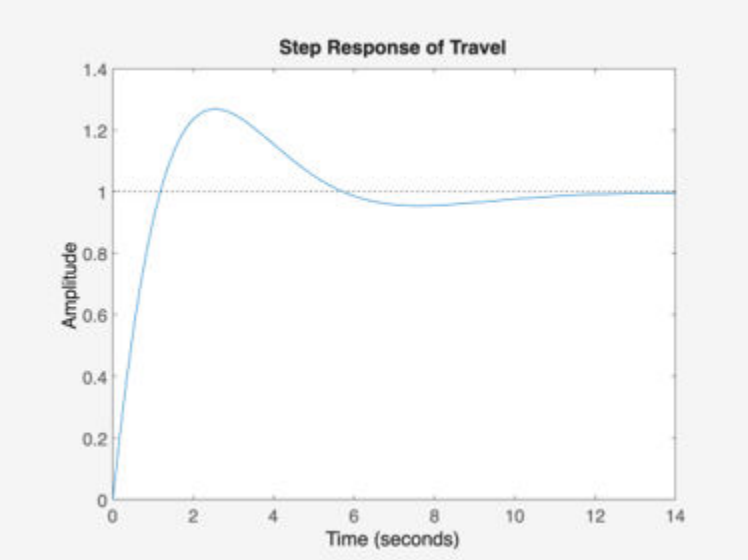
```
feedback_trav =

     1.274 s^2 + 0.8292 s + 0.1499
  ---------------------------------
  s^3 + 1.274 s^2 + 0.8292 s + 0.1499

Continuous-time transfer function.
```

Question 4

Step response for elevation

```
figure(9)
step(feedback_elev1, feedback_elev2, feedback_elev3)
title('Step Response of Elevation')

% Step response of travel
figure(10)
step(feedback_trav)
title('Step Response of Travel')
```





Question 5

```
fprintf('Characteristic information of step response for elevation 1:')
stepinfo(feedback_elev1)

fprintf('Characteristic information of step response for elevation 2:')
stepinfo(feedback_elev2)

fprintf('Characteristic information of step response for elevation 3:')
stepinfo(feedback_elev3)
```

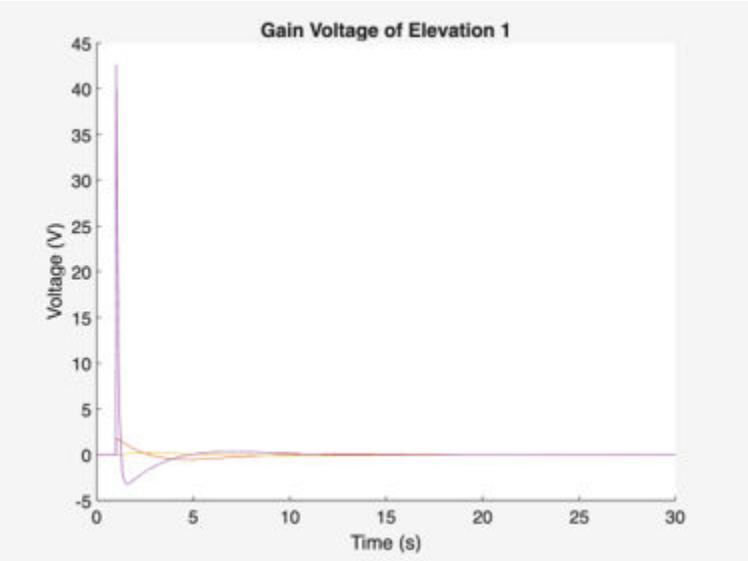
```
Characteristic information of step response for elevation 1:
ans =

  struct with fields:

        RiseTime: 1.3502
    TransientTime: 16.2627
     SettlingTime: 16.2627
      SettlingMin: 0.9552
      SettlingMax: 1.2591
        Overshoot: 25.9069
       Undershoot: 0
             Peak: 1.2591
         PeakTime: 3.7764

Characteristic information of step response for elevation 2:
ans =

  struct with fields:

        RiseTime: 7.5014
    TransientTime: 9.7511
     SettlingTime: 9.7511
      SettlingMin: 0.9001
```

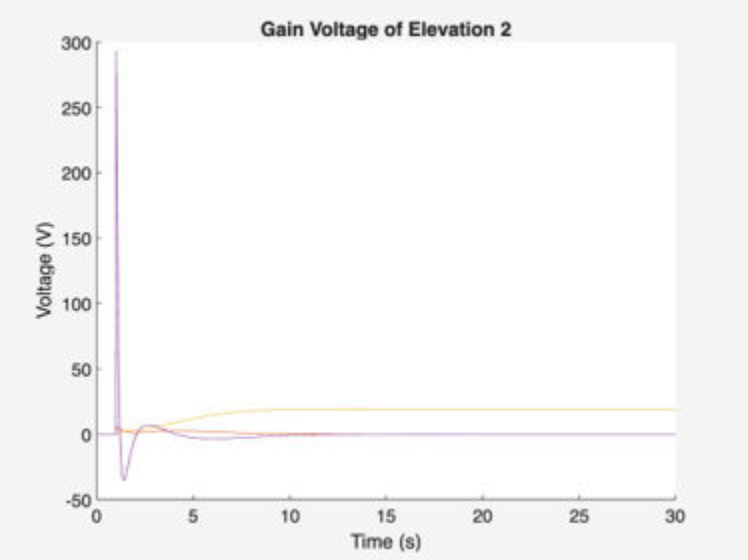
```
      SettlingMax: 1.0008
        Overshoot: 0.0822
       Undershoot: 0
             Peak: 1.0008
         PeakTime: 14.0644

Characteristic information of step response for elevation 3:
ans =

  struct with fields:

         RiseTime: 5.1223
    TransientTime: 8.7398
     SettlingTime: 8.7398
      SettlingMin: 0.9068
      SettlingMax: 0.9992
        Overshoot: 0
       Undershoot: 0
             Peak: 0.9992
         PeakTime: 13.7180
```

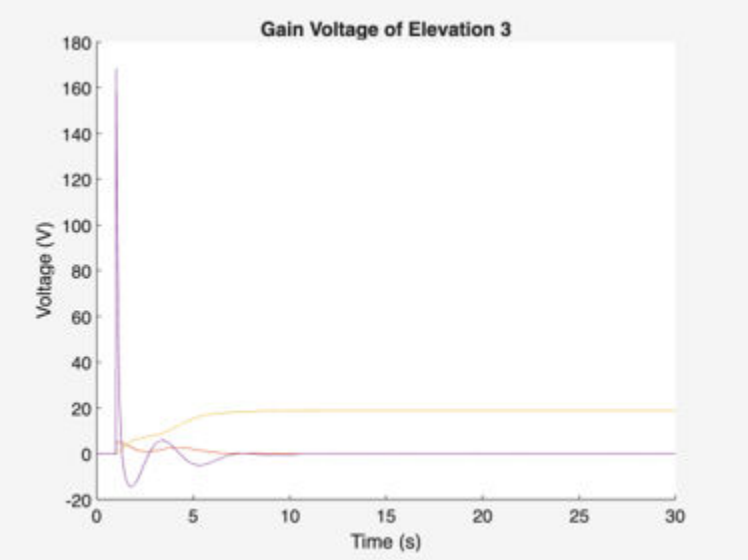
Question 6

```
%load elevationData1.mat
%load elevationData2.mat
%load elevationData3.mat

time = elev1(1, 1:end);

% Elevation 1
figure (11)
hold on
plot(CV1.time, CV1.signals(1).values)
plot(CV1.time, CV1.signals(2).values)
plot(CV1.time, CV1.signals(3).values)
hold off
title('Gain Voltage of Elevation 1')
xlabel('Time (s)')
ylabel('Voltage (V)')

% Elelvation 2
figure (12)
hold on
plot(CV2.time, CV2.signals(1).values)
plot(CV2.time, CV2.signals(2).values)
plot(CV2.time, CV2.signals(3).values)
hold off
title('Gain Voltage of Elevation 2')
xlabel('Time (s)')
ylabel('Voltage (V)')

% Elelvation 3
```

```
figure (13)
hold on
plot(CV3.time, CV3.signals(1).values)
plot(CV3.time, CV3.signals(2).values)
plot(CV3.time, CV3.signals(3).values)
hold off
title('Gain Voltage of Elevation 3')
xlabel('Time (s)')
ylabel('Voltage (V)')
```







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